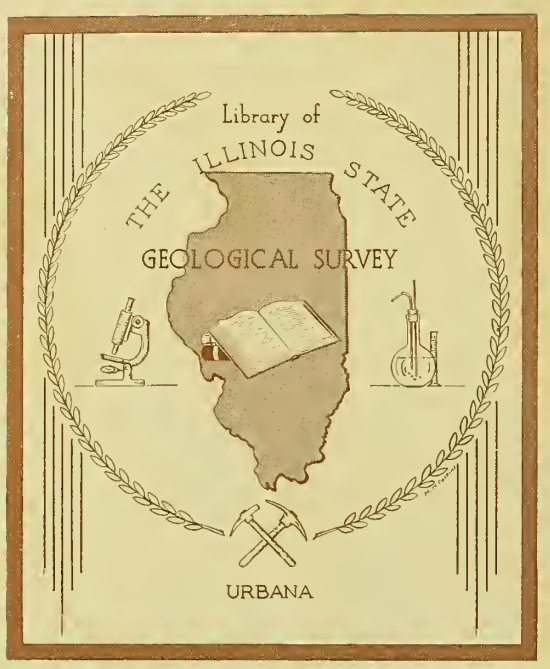

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SEDIMENTOLOGY OF A BEACH RIDGE COMPLEX AND ITS SIGNIFICANCE IN LAND-USE PLANNING

Norman C. Hester and Gordon S. Fraser

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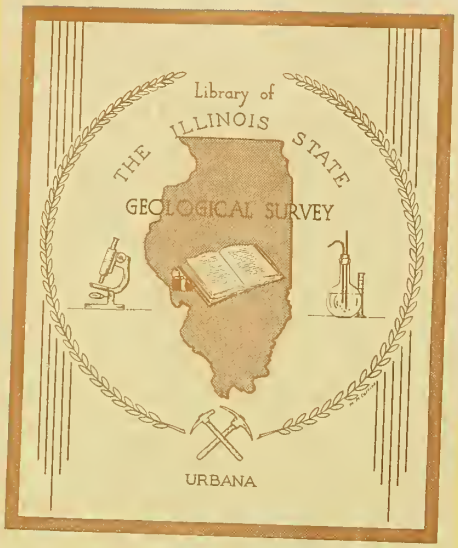
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SEDIMENTOLOGY OF A BEACH RIDGE COMPLEX AND ITS SIGNIFICANCE IN LAND-USE PLANNING

Sedimentary structures of storm-generated overwash deposits on Lake Michigan shoreline at the mouth of Kellogg Ditch, Camp Logan, Lake County, Illinois. (Sketch by Ruth C. Hester.)

SEDIMENTOLOGY OF A BEACH RIDGE COMPLEX AND ITS SIGNIFICANCE IN LAND-USE PLANNING

Norman C. Hester and Gordon S. Fraser

INTRODUCTION

A beach ridge complex, like that found along the shore of Lake Michigan in the Zion-Waukegan area, Lake County, Illinois, is a sediment body that is attached to shore, partially rises above water, and is formed by a disequilibrium caused by transportation into the area of an overabundance of sediments by long-shore current (Zenkovich, 1971).

The subaerial portion of the beach ridge complex consists of several distinct environments, including beach ridges, dune ridges, marshes (bogs), and modern beaches. These environments are integral parts of a large body of sediment that is susceptible to change by forces generated by the lake system. A beach ridge, where exposed to such forces, is a highly mobile, impermanent feature, for the same high-energy processes that constructed it can partially or completely destroy it. An awareness of this characteristic of a beach ridge complex is necessary before any effective plan for the use of such areas can be made.

This paper, therefore, emphasizes that a beach ridge complex is transitory, that erosion in some areas and aggradation in others is a natural phenomenon, and that the processes that have been controlling the distribution of these coastal features in the past will continue to be effective agents in the future.

Acknowledgments

We gratefully acknowledge the consideration and assistance of those who provided information that considerably reduced the research that had to be done. Included in this group are: Eugene Carter, Joseph McCloskey, John Mihovilovich, Michael Morris, and Norman Sandelin of Commonwealth Edison Company; George Fell and John Schwegman of the Illinois Nature Preserve Commission; John Camerio, Robert Corrigan, Phillip DeTurk, Helen Lyons, Robert Needham, and

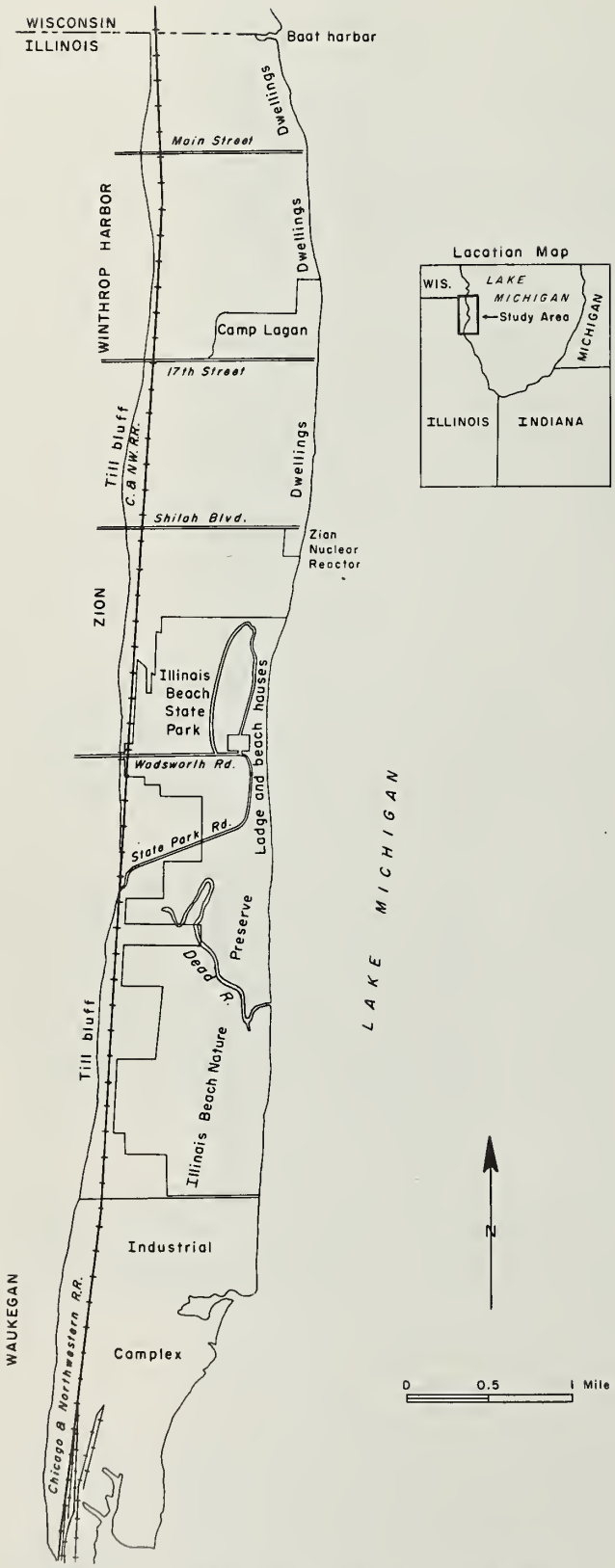


Fig. 1 - Extent and culture of the beach ridge complex in Illinois.

Don Weathers of the Illinois Department of Conservation; Phillip Fragassi of the Lake County Water District; Jerry Soesbee of the Lake County Park District; Don Kramer of the Illinois Division of Highways, District 1; Howard Peskator, Waukegan Water Company; and Jim Cunningham of Soil Testing Service. Carter Jenkins of Jenkins, Merchant, and Nankivil, Springfield, Illinois, was especially helpful in gathering the data from these diverse groups.

PHYSICAL SETTING

The beach ridge complex under investigation is located along the shore of southwestern Lake Michigan in Lake County, Illinois, and Kenosha County, Wisconsin (fig. 1). The area is covered by the U. S. Geological Survey maps of the Kenosha (Wis.), Zion (Ill.-Wis.), and Waukegan (Ill.) 7.5-minute quadrangles. Except for the lands set aside for Illinois Beach State Park and Illinois Beach Nature Preserve, the area, particularly the shoreline, has been occupied by man. Although most of the structures along the shoreline are dwellings, industry has taken over two areas—one south of the Nature Preserve and the other east of Zion. The subaerial beach ridge complex, which consists principally of beach ridges, dunes, and marshes, trends north-south from just southeast of Kenosha, Wisconsin, to just east of Waukegan, Illinois, a total length of 14 miles. It is bounded on the west by the generally north-south trending till bluff and on the east by Lake Michigan. The subaerial portion of the beach ridge system is 1.1 miles wide in the area of the Illinois Beach Nature Preserve, approximately 0.9 miles wide along Wadsworth Road, 0.7 miles wide at the Illinois-Wisconsin boundary, and is essentially absent just southeast of Kenosha, Wisconsin. The subaqueous portion of the beach ridge

complex forms an apron of sand that slopes gently eastward and ends 1 to 1.5 miles from shore.

The subaerial portion of the beach ridge complex consists of several environments (fig. 2), the major ones being beach ridges covered with trees and shrubs, dune ridges covered with shrubs and grass, marshes covered with reeds and grass, and modern beaches with little or no vegetation.

In the area of Illinois Beach State Park and south of it, the beach ridge complex appears surficially as an orderly arrangement of beach and dune ridges, which may be recognized on aerial photographs (fig. 3) by their linear and gently curving form. Because such slight differences in relief are apparent between the ridge and the adjacent lowland or marsh, the ridges are sometimes defined only by subtle changes in vegetative cover that show up on infrared aerial photographs. North of the State Park, almost to the state line, however, the ridges are not so well defined and are interrupted by low-lying, hummocky sand plains and marshes. North of the state line, marshes are essentially absent and the area consists of eolian sand plains.

METHOD OF STUDY

Data were collected by drilling with the Illinois State Geological Survey's Mobil B-30S, hand augering, trenching the beach, excavating outcrops in drainage ditches, and studying topographic maps and vertical and oblique aerial photographs.

Forty-six holes were drilled through the sand body to the underlying till (fig. 4). Eighteen holes were hand augered, principally in the dune and marsh areas, which were inaccessible to the drill rig. Six beach profiles were trenched and ten outcrops were excavated in the study area. To supplement our drill holes, records were made available by Commonwealth Edison Company for 78 drill holes in the subaerial portion of the sand body. The Illinois Division of Highways, District 1, provided data from 48 holes. Offshore drilling data collected from 30 sites for aqueduct investigations were provided by Commonwealth Edison Company, the Lake County Water District, and the Waukegan Water Works.

PRESENTATION OF DATA

Thickness Distribution

The data gathered from the onshore drill holes that penetrated the sand body to the underlying till were used to construct a map of the thickness of the sediment (fig. 5). The isopachs show that in the subsurface the beach ridge complex is a linear body of sediment. The sand body thickens from west to east in two steps to an average thickness of 30 feet in the area of the modern beach. It trends north-south and ranges in width from 0.75 to 1.1 mile, and its length from the southern tip to the Illinois-Wisconsin border is about 9 miles. Our data are not adequate for mapping the thickness of the subaqueous

A. Beach ridge frequently tree covered; rises in slight relief above adjacent marshes.

B. Dune ridge occupied by shrubs and grasses stands as much as 10 to 15 feet higher than adjacent marshes, beaches, or eolian sand plains.

C. Marsh, occupied by reeds and swamp grass; frequently inundated.

D. Modern beach with little or no vegetation.

Fig. 2 - Major environments of the beach ridge complex.

Fig. 3 - Oblique aerial view of the beach ridge complex along the southwest shore of Lake Michigan. (Photograph taken by Paul DuMontelle of the Illinois State Geological Survey from a point just east of Waukegan near the southern end of the sediment body.)

portion of the complex, but the offshore drill hole data show that the sand body thins to the east and either pinches out or changes in lithology to silt and clay in about a mile or a mile and a half offshore.

Geologic Provinces

The area can be divided into four provinces based on soil type, geomorphology, and sediment texture (fig. 6). Province I includes the sand and sand and gravel in the modern beach areas and also the fine to medium sand in

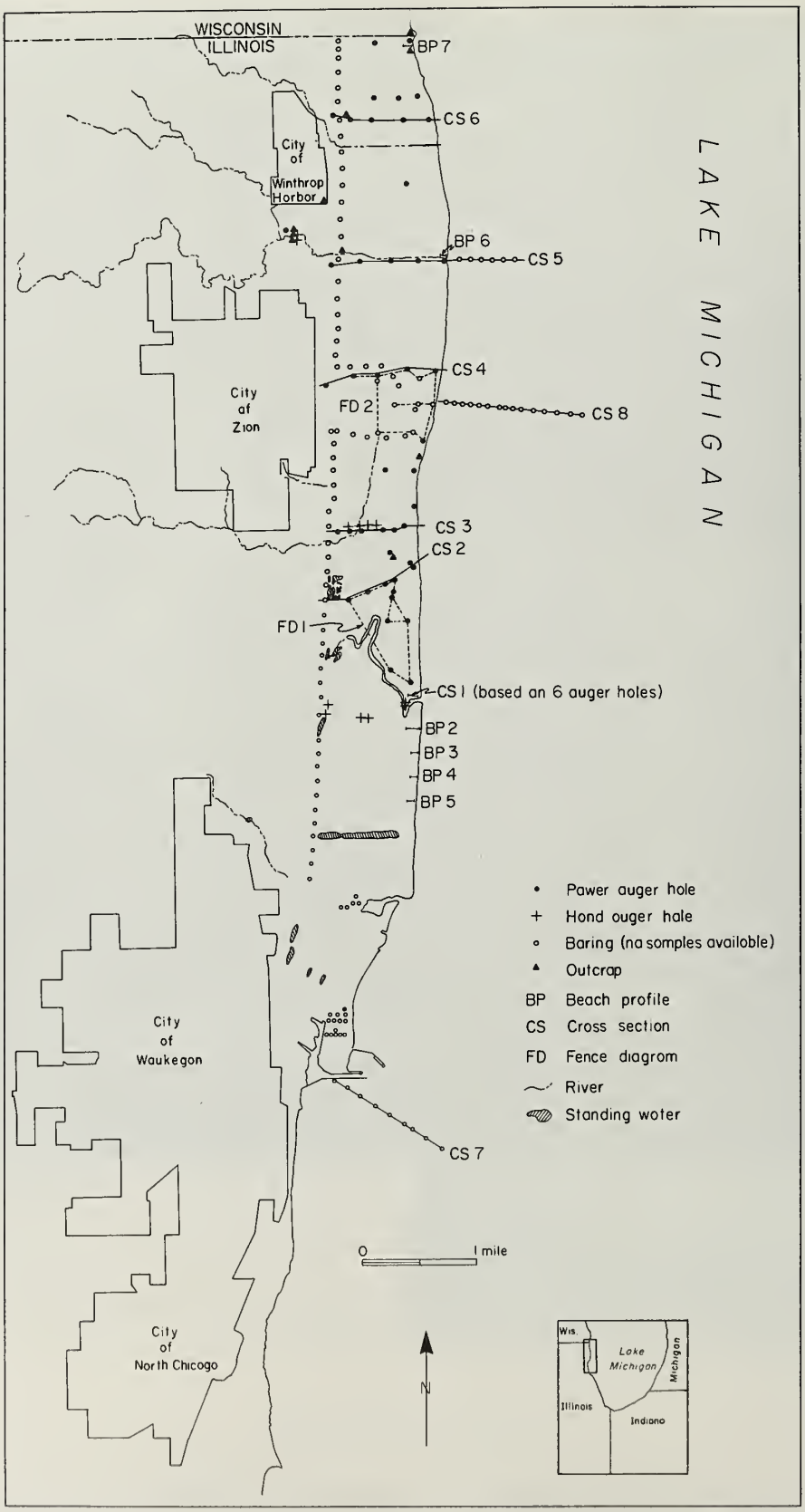


Fig. 4 - Location of datum points, cross sections, beach profiles, and fence diagrams.

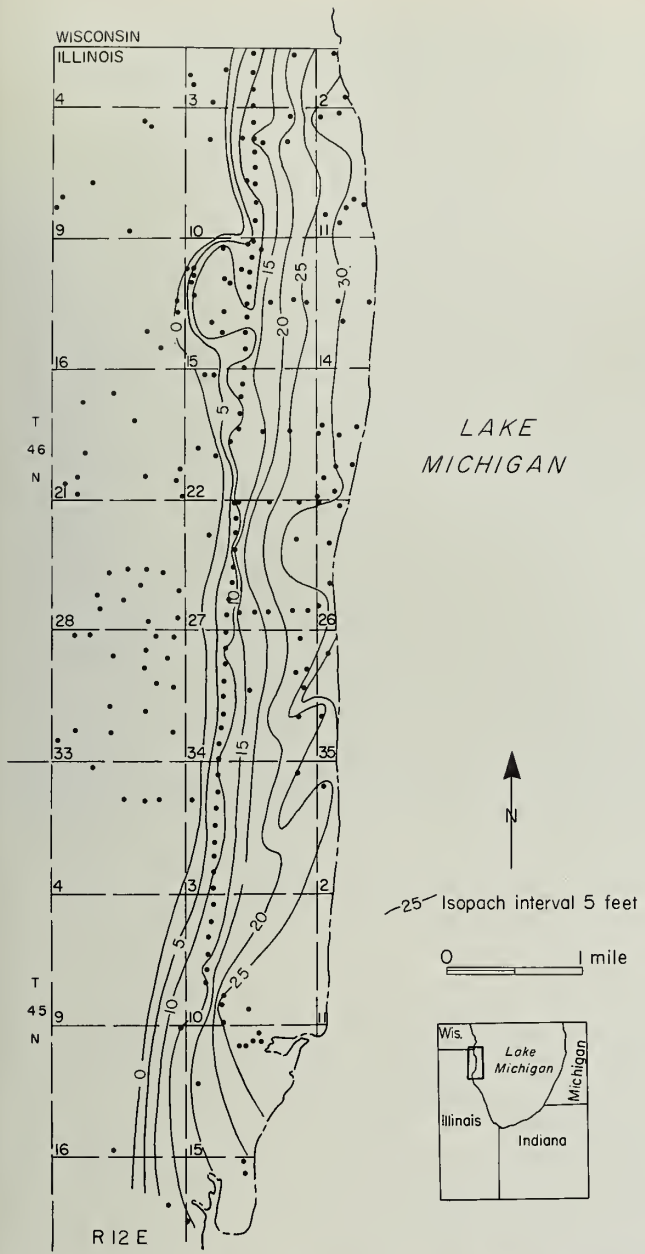


Fig. 5 - Thickness of sediment of beach ridge complex. Datum points are shown.

the well developed, prominent, linear dune ridges adjacent to the beach. These areas contain very little vegetation and are susceptible to eolian erosion, which produces blow-outs. Because of the youthful nature of these areas, no soils have developed.

Province II includes fine to medium sand of eolian origin in gently rolling and distinctly ridged areas. Natural vegetation consists of a sparse cover of drought-resistant grasses, shrubs, and trees. A soil profile of 2 to 4 inches has developed on these sands, indicating that they are older than the beach and ridge sands of Province I. Exposures of this profile may be seen in the borrow pits along the service road south of Illinois Beach State Park's service garage, NE¼ NE¼ Sec. 34, T. 46 N., R. 12 E.

Province III includes fine to medium sand in level areas or ridges with slight relief. Natural vegetation is swamp grass. These deposits contain the best developed soil profiles in the area. As can be seen in figure 6, they generally occur in the northern and western portions of the study area. According to Paschke and Alexander (1970, p. 21), a typical profile contains at the surface about 10 inches of black loamy sand rich in organic material. The subsoil is a brownish gray loamy sand about 8 inches thick, which grades into a yellowish brown sand. Underlying the soil are light gray calcareous sands. An example of the soil profile may be seen along the beach about 750 feet south of the Illinois-Wisconsin border (fig. 7).

Province IV consists of the modern marsh developed on mixed layers of sand, silt, and clay. Vegetative cover consists of reeds and marsh grasses. The development of peat or muck depends on the geographic position in the beach ridge complex. In the southern part of the study area, no peat or muck is present, and the bog material consists of modern vegetation. To the north, in the area west of the Illinois Beach State Park campground, the bog has been in existence long enough for peat to develop. Two samples were taken for radiocarbon

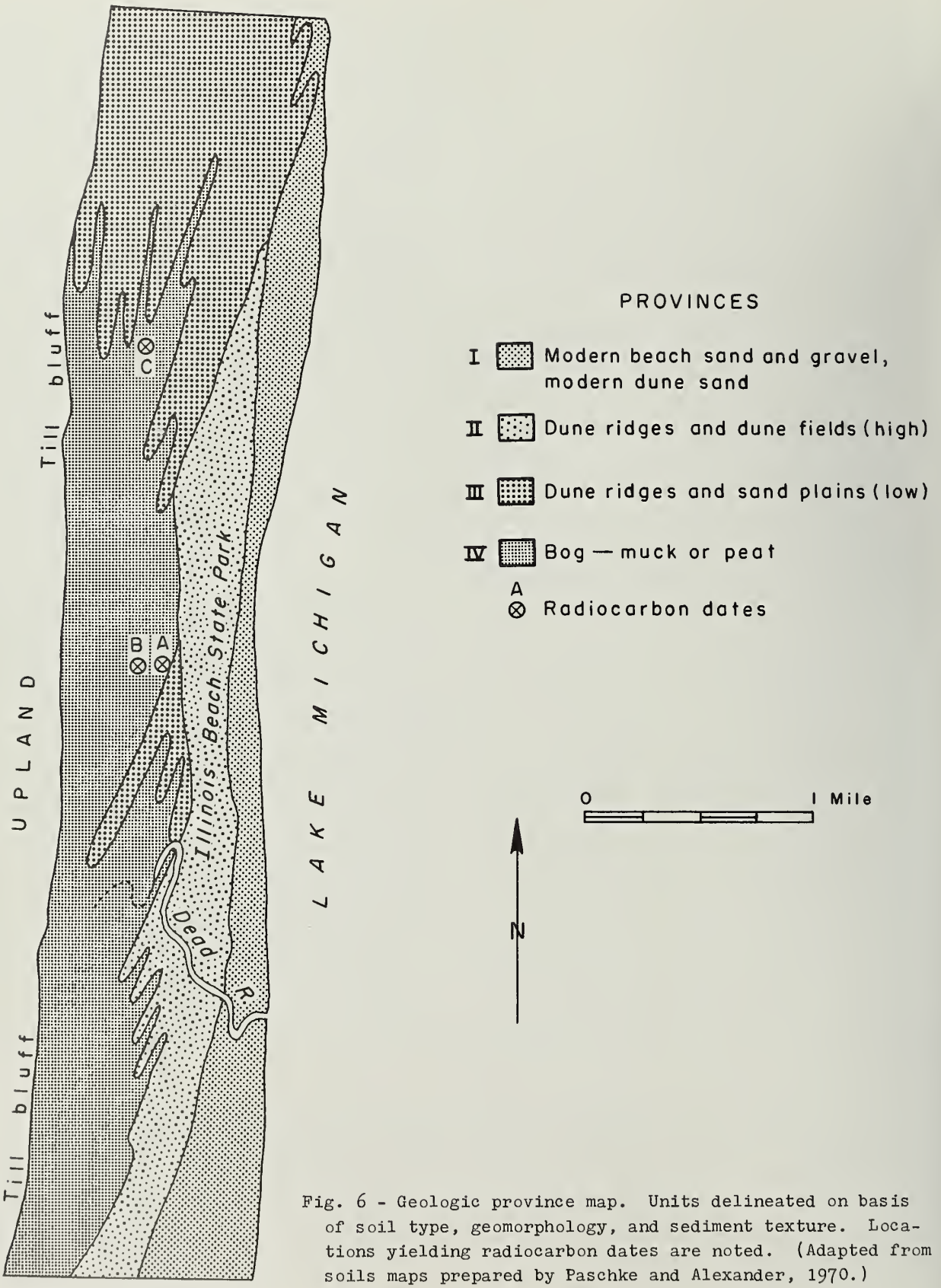


Fig. 6 - Geologic province map. Units delineated on basis of soil type, geomorphology, and sediment texture. Locations yielding radiocarbon dates are noted. (Adapted from soils maps prepared by Paschke and Alexander, 1970.)

Fig. 7 - Outcrop along beach exposes cross section of ridges and swales of ancient dune ridges with thick soil profile.

dating from hand auger holes just north of Wadsworth Road (fig. 6, A, B). Sample A was dated as 715 ± 75 (ISGS-168) radiocarbon years B.P., and Sample B was dated 540 ± 75 (ISGS-182) radiocarbon years B.P. Just north of Shiloh Boulevard in the bog west of the Commonwealth Edison power plant, a sample (C) of peat was taken and dated at 1165 ± 75 (ISGS-169) radiocarbon years B.P. Figure 8 shows the position of the peat in the auger holes where the three samples were taken. In the area east of Winthrop Harbor, no peat, muck, or organic clays have been found.

The distribution of Provinces I, II, and III demonstrates that the oldest beach ridge sediments (those of thickest soil development) are located to the north and west, and that the sediments become younger to the south and east where soil is absent. The distribution of peat and the radiocarbon dates also indicate a southward decrease in age for the sediment body.

Size Distribution of Surface Sediments

Each major sedimentological environment that can be recognized in the beach ridge complex—beach-nearshore, dune, marsh, offshore—is characterized by a unique range of grain sizes.

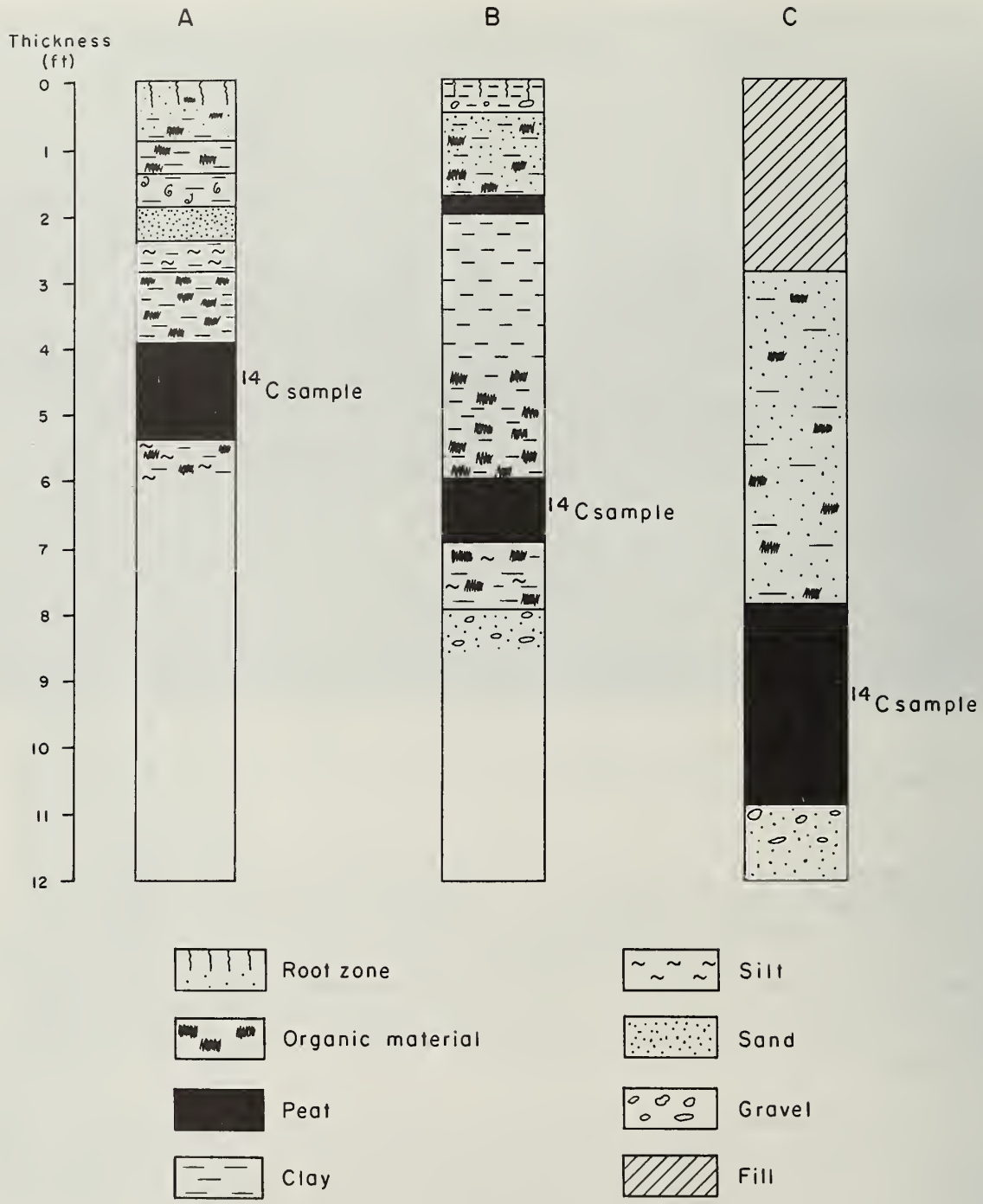


Fig. 8 - Sediments found in three auger holes and location of peat samples that yielded radiocarbon dates.

The beach is composed of a highly varied assemblage of sediments whose distribution appears related to the distribution of forces as waves wash onto the shore. Figure 9 shows a set of cumulative curves taken from a beach profile developed soon after a storm. The coarsest material, coarse sand and gravel (curves I, V, and VI), is found nearest the area where waves break on shore, and the sands become progressively finer (curves II, III, and IV) as distance from the water increases. The finest material on the beach (curves VII and VIII) occurs where winds have reworked the sand.

Dunes develop over beach ridges in areas where beach grasses can trap and stabilize wind-transported sand. The dune material is composed of a uniformly medium sand that appears to show no variability with respect to position in the dune (fig. 9).

Marshes occur behind beach ridges where standing water acts as a trap for fine-grained sediments washed off the till bluff or transported from the dunes by wind. The sediments of the marsh are composed of various mixtures of sand, silt, and clay (fig. 10). While the amount of sand varies greatly, the ratio of silt to clay remains relatively constant and they occur in approximately equal amounts. The sediments consist primarily of silt and clay near the center of the marsh (curves I, II, III, and IV, fig. 9) but become sandier toward the margins (curves VII, VIII, IX, and X). The mode (most frequently occurring size) of the sands of the marsh coincides with that of the dunes (fig. 9), which indicates that they also are wind derived.

The subaqueous (offshore) sands display the finest sand textures in the beach ridge complex (fig. 9). They generally consist of medium-fine to fine sands with small admixtures of fine gravel. The sands become finer farther from shore, the amount of gravel decreases, and the amount of silt increases (fig. 10).

In addition to the textures characteristic of these environments, two other textural types are found associated with the sand body. On its western margin, colluvial-alluvial material is found near the base of the slope of the till bluff and in stream valleys cut through the bluff. This material is composed of silty, clayey sand and gravel that washes down the slope (fig. 10) and clay rich in organic material. The amount of sand and gravel varies, but the ratio of silt to clay remains about 4:1 or 5:1. Alluvial sand is found along the valleys debouching onto the beach ridge area. It is moderately sorted, medium to medium-fine, and essentially free of clay and silt.

Glacial till underlies the beach ridge complex and is present in the upland to the west. The till is from 10 to 35 percent sand. Like the colluvial-alluvial material, the ratio of silt to clay remains constant at about 4:1 but the amount of sand and gravel varies, indicating that the source of the colluvial-alluvial material may have been the till.

An additional textural type is frequently encountered at the top of the till in the subsurface. It consists of coarse gravel up to 3 feet thick and is referred to by local drillers and construction workers as "the boulder bed." This bed probably formed as a lag concentrate as silt, clay, and sand were eroded from the till, leaving only the coarse gravel.

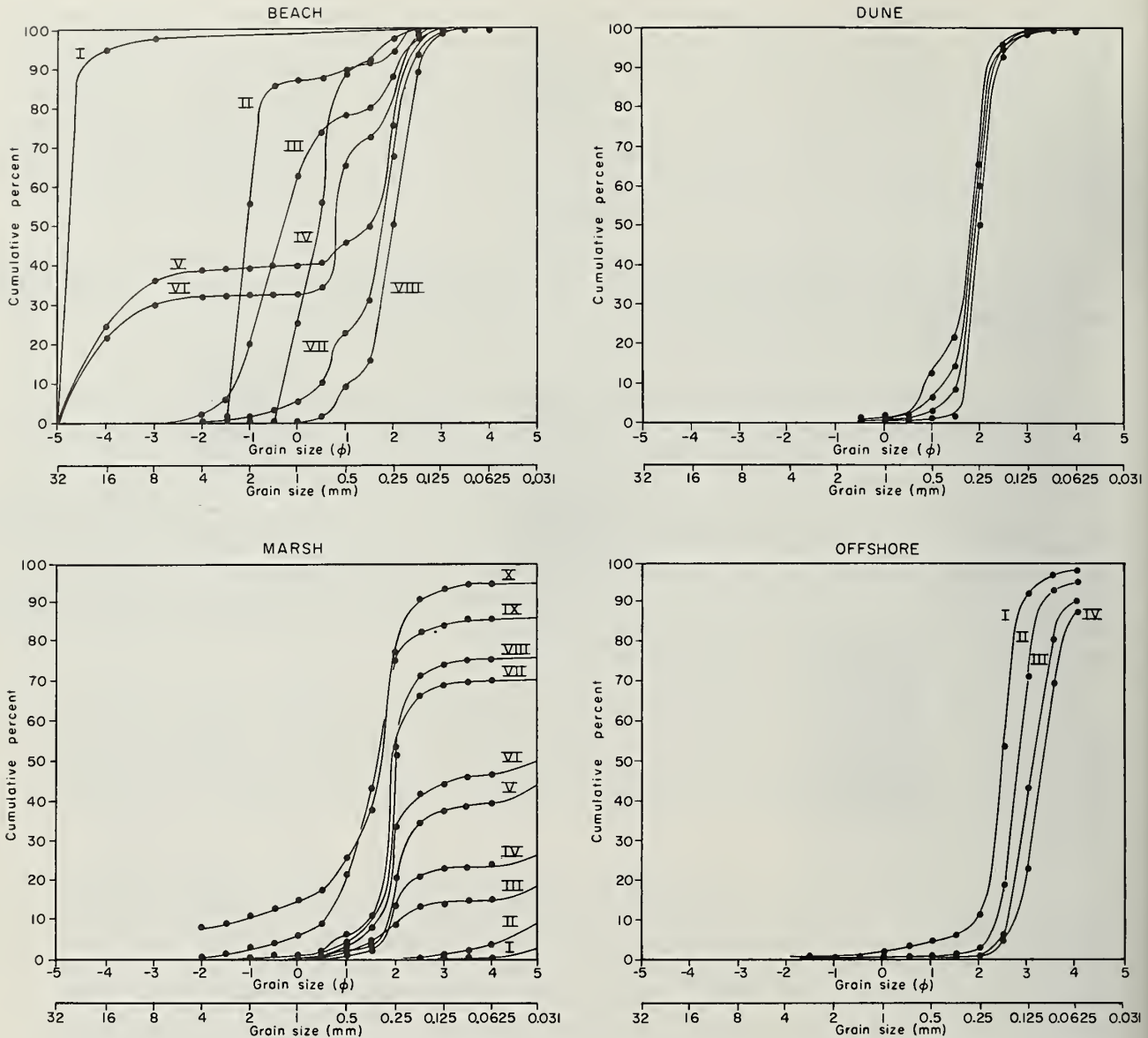
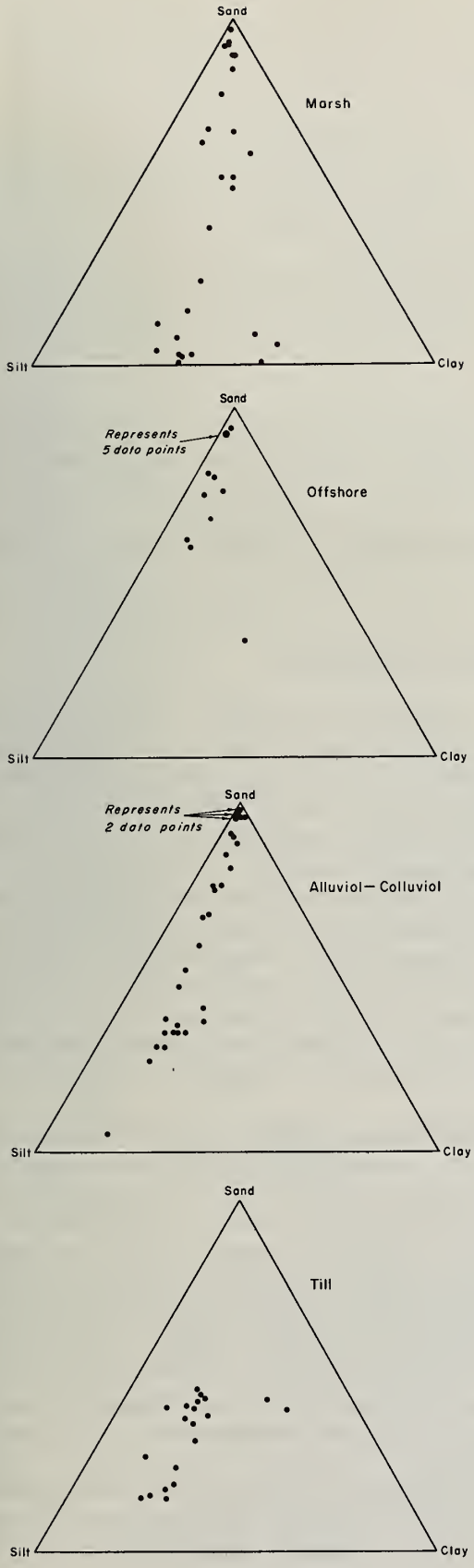


Fig. 9 - Cumulative curves show size distribution of sediments from various environments. Curves were constructed from data collected by passing sediment through a nest of U. S. Standard sieves at half phi intervals.

Distribution of Sediment in the Subsurface

Several distinct textural types that varied both laterally and vertically were recognized in the subsurface and could be related to the textures found in the modern sedimentological environments. Using these similarities, we were able to reconstruct the pattern of lateral distribution and the vertical sequence of the major environments in the subsurface.

Figure 11 is a generalized cross section running from west to east through the sand body. It was derived from five actual cross sections constructed from our drill data and shows the pattern of the environments as they invariably occur in the subsurface.



The basal portion of the sand body consists of the fine sands of the offshore environment. This facies thins to the west and generally does not occur west of the first step in the basal till. It also thins lakeward as the whole sand body thins.

Overlying the fine sand is the gravel and coarse sand of the beach and nearshore environments. This unit maintains a relatively constant thickness toward the west, except where it thins slightly under the marsh. The unit thins quite abruptly lakeward, however, generally not extending more than 1000 feet from shore.

The medium sands of the dune environment are thickest in the vicinity of the modern beach in the southern part of the study area; they generally grade westward into the organic clay and silt of the marsh. To the north, however, the marsh is thinner and less extensive, and the dune ridges have spread out to form a blanket-like dune field only a few feet thick.

Near the western margin of the sand body, colluvial-alluvial material is found in many places at the base of the slope of the bluff. It occurs both under and above the sediments of the other environments.

The distribution and vertical sequence of these sedimentary environments in the subsurface indicate that the sand body has been accreting eastward. Offshore sands were gradually built up, forming an underwater apron at the same time material was being washed down the till slopes to form the alluvial-colluvial deposits. The beach and nearshore gravels built over these deposits, beginning near the bluff and gradually accreting eastward. Dune deposits were formed where

Fig. 10 - Sand-silt-clay percentages in the various types of sediments. Data were collected by the pipette method.

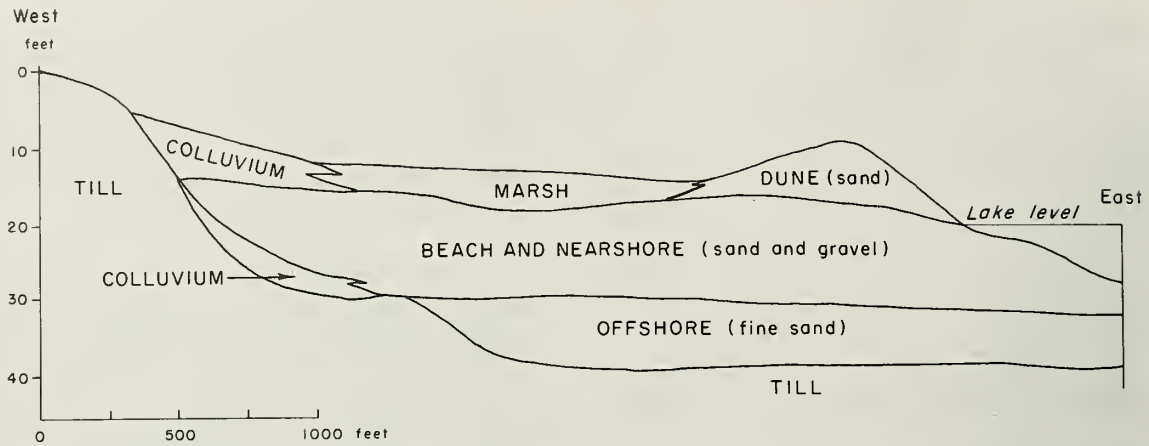


Fig. 11 - Generalized cross section of the sand body from west to east shows subsurface distribution of various major environments (textures). Illustration constructed from five drill hole cross sections.

prominent beach ridges were stabilized by vegetation, and marsh deposits developed behind them.

Interpretation of Aerial Photographs

Aerial photograph mosaics (scale, 1 inch = 400 feet) were the basis for a lineament map (fig. 12). This illustration shows linear features recognizable on the photographs instead of topographic forms (such as ridges) that stand in relief. Many of the lineaments appear to be parts of ancient beach strands and, therefore, represent old shorelines that existed at various times as the sand body developed. Some of the lineaments, however, such as those in the extensive marsh west of the Illinois Beach State Park and the Nature Preserve, have essentially no obvious surface expression, as figure 13 illustrates. The lineaments instead are represented by differences in vegetation. A detailed drill hole profile (fig. 14) illustrates that the differences in vegetative cover are a reflection of minor differences in elevation of the surface of the sand that serves as the marsh substrate. These buried ridges, which have generally less than 3 feet of relief, are believed to be ancient strandline features.

Observations made on the angles that the lineaments (old beach strands) make with the modern Lake Michigan shore show a pronounced truncation in the northern portion of the beach ridge complex, particularly north of the Illinois-Wisconsin border. There, only remnants of the original beach ridges remain. The lineaments trend generally N 20° E; and make an angle of about 40 degrees with the modern beach in the area of the Illinois-Wisconsin border. Recent erosion in the Lake County Forest Preserve, just south of the state line, exposes cross sections of the ridges and swales, which contain soils more than a foot thick developed on dune and beach sands (fig. 7). These exposures demonstrate that a large part of the older beach ridge complex, which at one time extended much farther to the northeast, has been removed by erosion and transgression of the lake.

In Illinois Beach State Park and southward to the tip of the sand body, the lineaments nearly parallel the modern beach. This pattern indicates that new beach ridges in this area have developed in recent times. Accretion rather than erosion is therefore the dominant process in this area of the beach ridge complex.

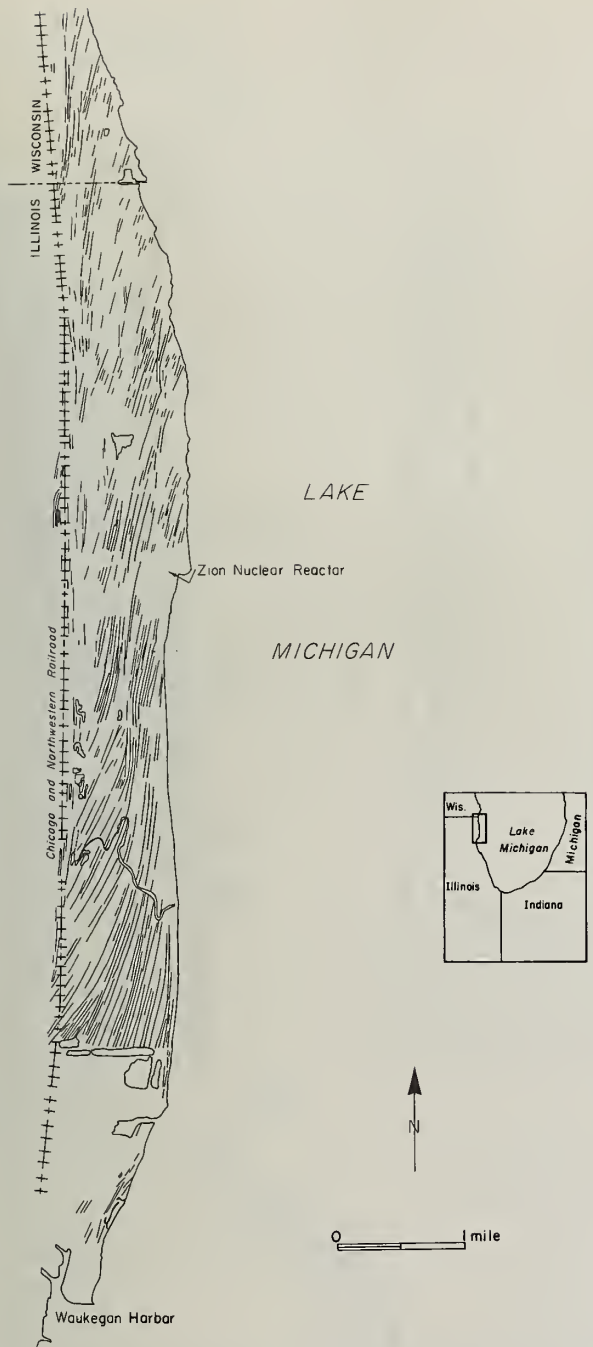


Fig. 12 - A lineament map constructed by tracing and enhancing linear features distinguishable on vertical aerial photograph mosaics at a scale of 1 inch equals 400 feet.

SEDIMENT DISPLACEMENT

The foregoing data indicate that the beach ridge complex is transitory in nature and that a progressive southward displacement of this body of sediment has taken place. Such migration of sediment is a natural occurrence that results from forces generated by the lake system, which includes erosion, transportation, and deposition. Although erosion is but one of the mechanisms involved, it has played an important role in the development of the beach ridge complex and it has recently been brought into sharp focus as a result of man's occupation of the lake front.

LAKE SHORE EROSION

Ancient Erosion

Erosion along the shore of Lake Michigan has long been an agent in shaping the beach ridge complex to its present appearance. Evidence for past erosion can be recognized both on the surface and in the subsurface. On the surface we recognize periods of erosion as topographic disconformities caused by truncation of lineaments. Several of these features appear in the area (fig. 15). One of the most striking disconformities is found just west of the campgrounds of Illinois Beach State Park. A detail of the lineament map of this area (fig. 16) suggests that the lake transgressed to line A in the past. Although no exact date can be determined, dates of 715 ± 75 and 540 ± 75 radiocarbon years B.P. on the two peat samples from Wadsworth Road provide us a range of time to work with in establishing when the erosion occurred. If the marsh originated penecontemporaneously with the development of the northeast-trending lineament system, then truncation took place sometime after 1200 to 1400 A. D. However, it is possible that the marsh developed as a result of the erosion of the shore to line A and the subsequent accretion of ridges and dunes in area B. In that case, truncation would have taken place sometime shortly before the 1200 to 1400 A. D. age range.

In the subsurface, erosional disconformities are recognized as conspicuous changes in sediment grain sizes. Several holes drilled along Wadsworth Road (fig. 17) show the offshore fine sand at the base and dune and marsh sediments as the uppermost units. The beach and nearshore sediment in this cross section, however, undergoes a marked change in range of grain sizes in going from PA-9 to PA-7. The beach and nearshore sediment in PA-9 consists of medium to coarse sand with granules, whereas the beach and nearshore sediment in PA-7 contains a considerable amount of gravel throughout.

Fig. 13 - View southwest over marsh west of Illinois Beach State Park camping grounds, showing lack of surficial expression of the beach ridge lineaments.

This abnormally thick deposit of sand mixed with gravel continues lakeward in PA-8. It is likely that the process responsible for the erosion to the west near PA-5 developed a concentration of gravel as a lag, which was accreted in the area from PA-7 to PA-8. The same topographic disconformity was recognized in the subsurface in a series of holes drilled along the road to the Illinois State Park lodge, south of Wadsworth Road.

Shoreline Changes

The erosion in the northern part of the beach ridge complex and the deposition to the south have been the agents that have developed the present configuration of the Lake Michigan shoreline.

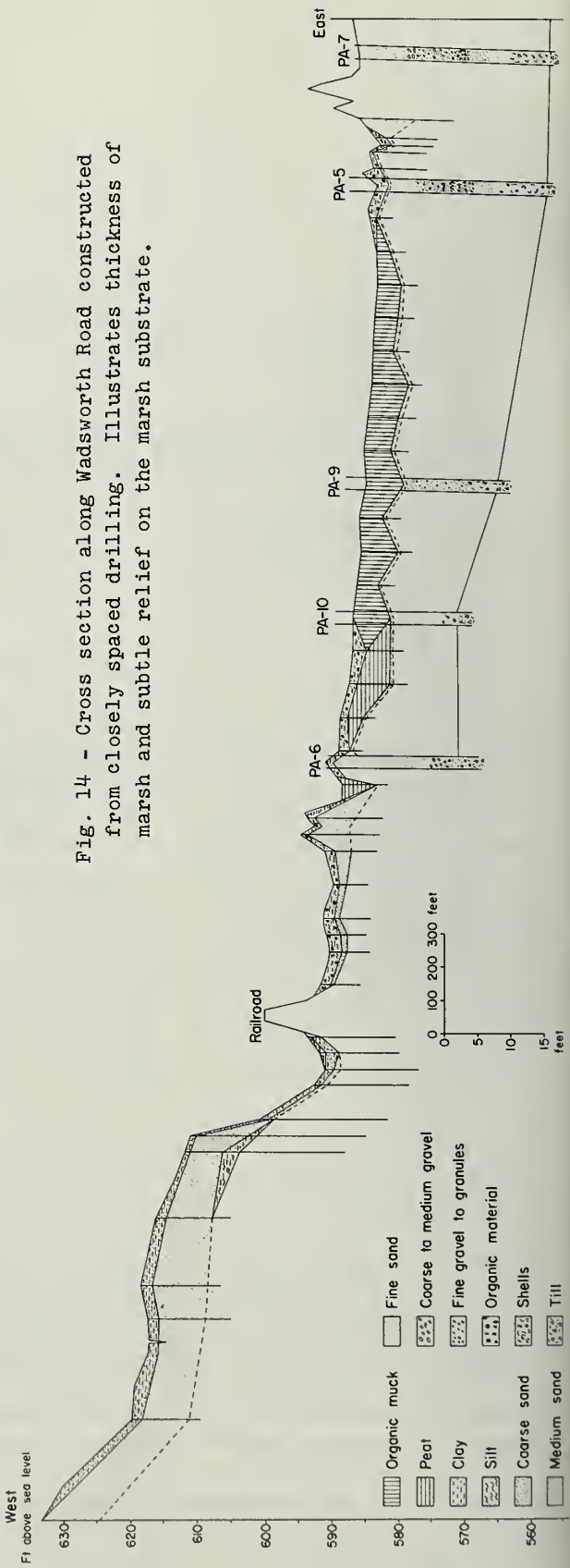


Fig. 14 - Cross section along Wadsworth Road constructed from closely spaced drilling. Illustrates thickness of marsh and subtle relief on the marsh substrate.

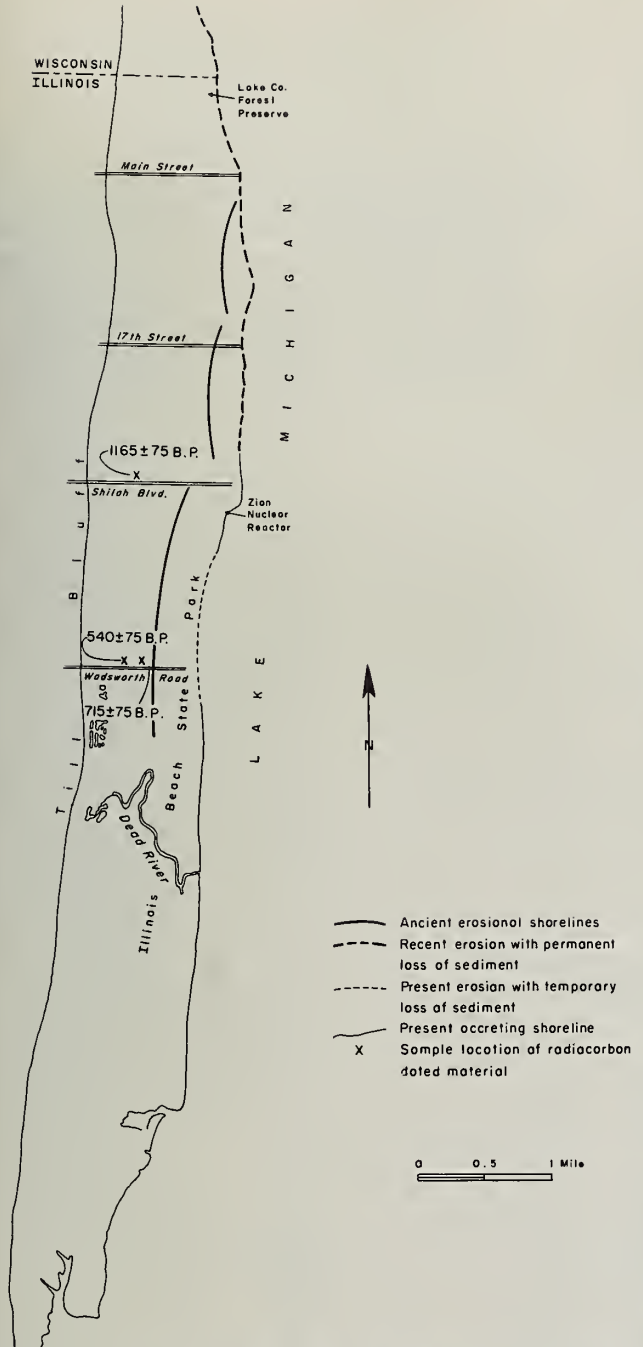


Fig. 15 - Erosional shorelines, past and present. With the exception of the continuous erosion of the shoreline along the till bluff, which preceded the formation of the beach ridge complex, the traces of old erosional shorelines appear in arcuate segments, suggesting localized erosion. They are concentrated in the northern portion of the map because this beach ridge complex is characterized by erosion at the north and deposition to the south.

Aerial photographs show very clearly the effect of shoreline processes. Figure 18 comprises two aerial photograph mosaics—(A) the area from just south of Camp Logan to 1.5 miles north of the Illinois-Wisconsin border and (B) the area from just north of Wadsworth Road to the industrial complex east of Waukegan. Figure 18A shows a very irregular shoreline, with little or no beach in most areas, and a number of promontories extending into the lake. The projections are actually home sites—those that remain after the extensive erosion of the past few years.

Figure 18B shows a shoreline with rather wide, well developed beaches, which indicate that the shoreline of this area is accreting. The shore processes are erosion to the north and deposition to the south.

The shoreline and underwater topography in the area of Illinois Beach State Park was charted in 1872-1873 and 1909-1911 by the U. S. Lake Survey. Additional surveys along the coast were conducted in 1946-1947 by the Illinois Division of Waterways and the U. S. Army Corps of Engineers, and in 1950-1955 by the Illinois Division of Waterways (1958). From these charts it is possible to reconstruct the changes in the morphology of the coast along the southwest shore of Lake Michigan during an 80-year period.

Figure 19 shows the changes in the position of the shoreline. A general shift of the shoreline to the west north of 21st Street is evident, indicating that a considerable amount of material has been removed since 1872. From 21st Street south to the outlet of Dead River the coastline has remained essentially constant, while south of Dead River the shoreline has moved lakeward, indicating deposition of material along the southern margin of the sand body.

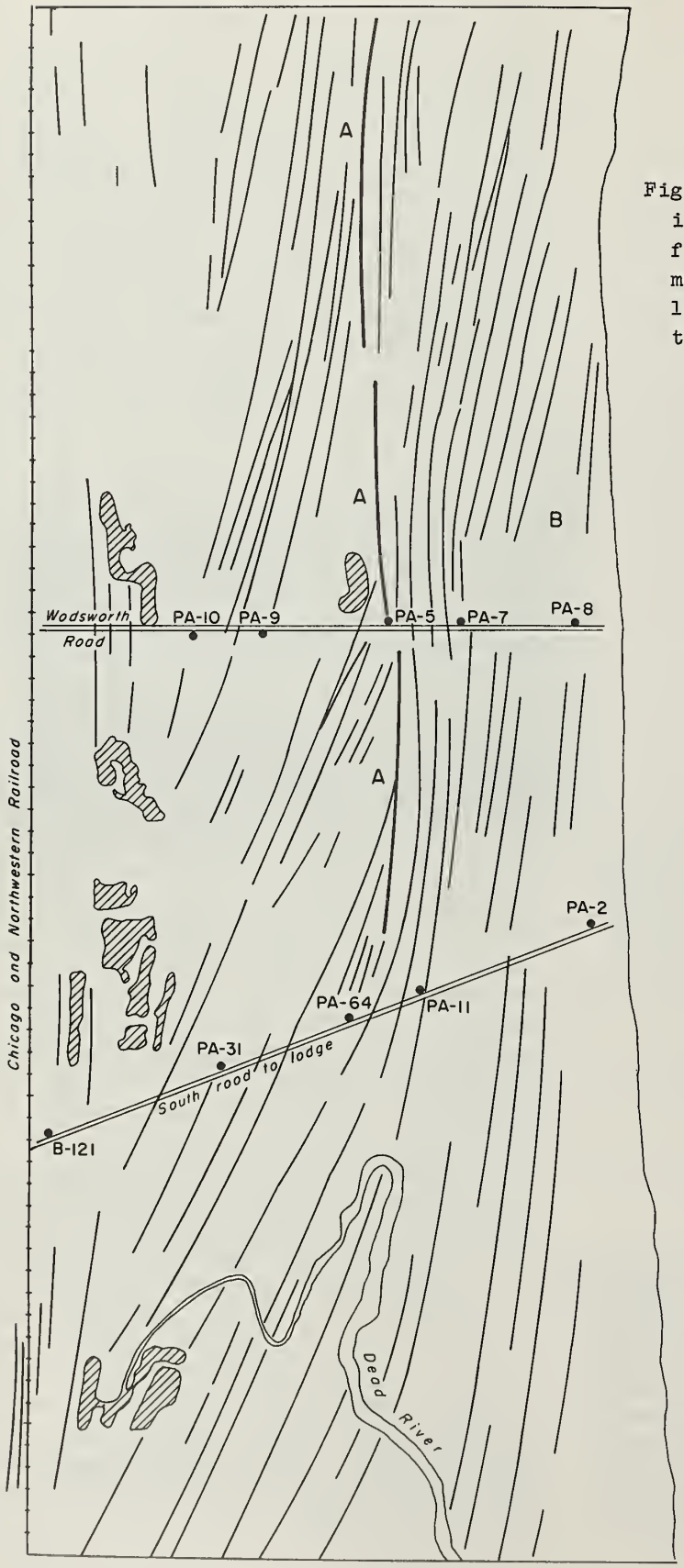


Fig. 16 - Detail of lineament map (fig. 12) illustrates prominent topographic disconformity expressed as truncation of lineaments (heavy line passing through hole location PA-5). For exact location of this segment of map see figures 1 and 4.

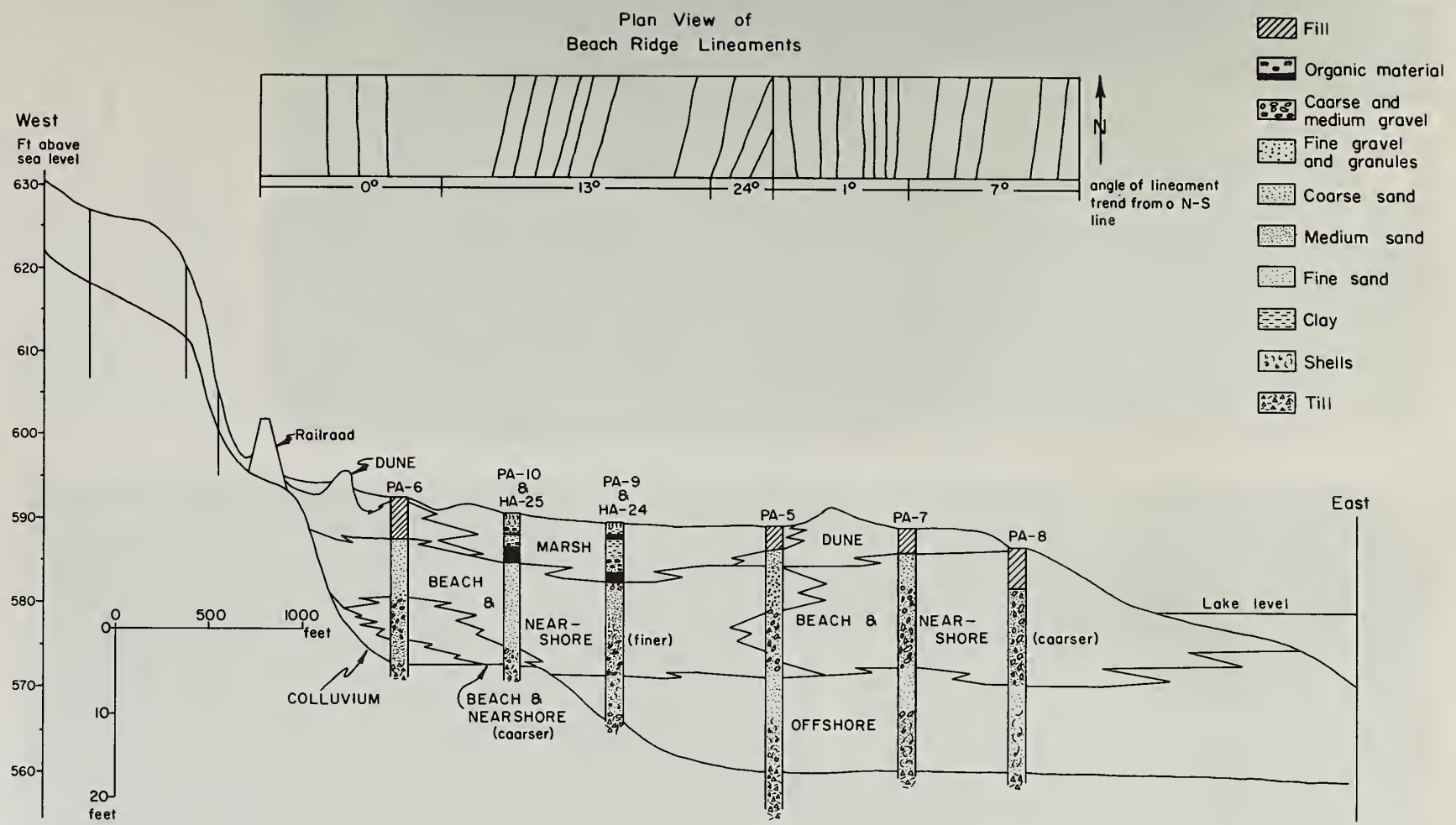


Fig. 17 - Drill hole profile CS 3 along Wadsworth Road shows subsurface distribution of sediment types. Abrupt lateral change in sediment size (texture) occurs between PA-9 and PA-7 and indicates topographic disconformity in the subsurface.

Fig. 18 - Vertical aerial photograph mosaics of the beach ridge complex. For locations see figure 3. (A) Area from immediately south of Camp Logan to 1.5 miles north of the Illinois-Wisconsin border. (B) Area from just north of Wadsworth Road south to the industrial complex at the southern end of the beach ridge complex. (Photographs provided by Commonwealth Edison Co., 1970.)

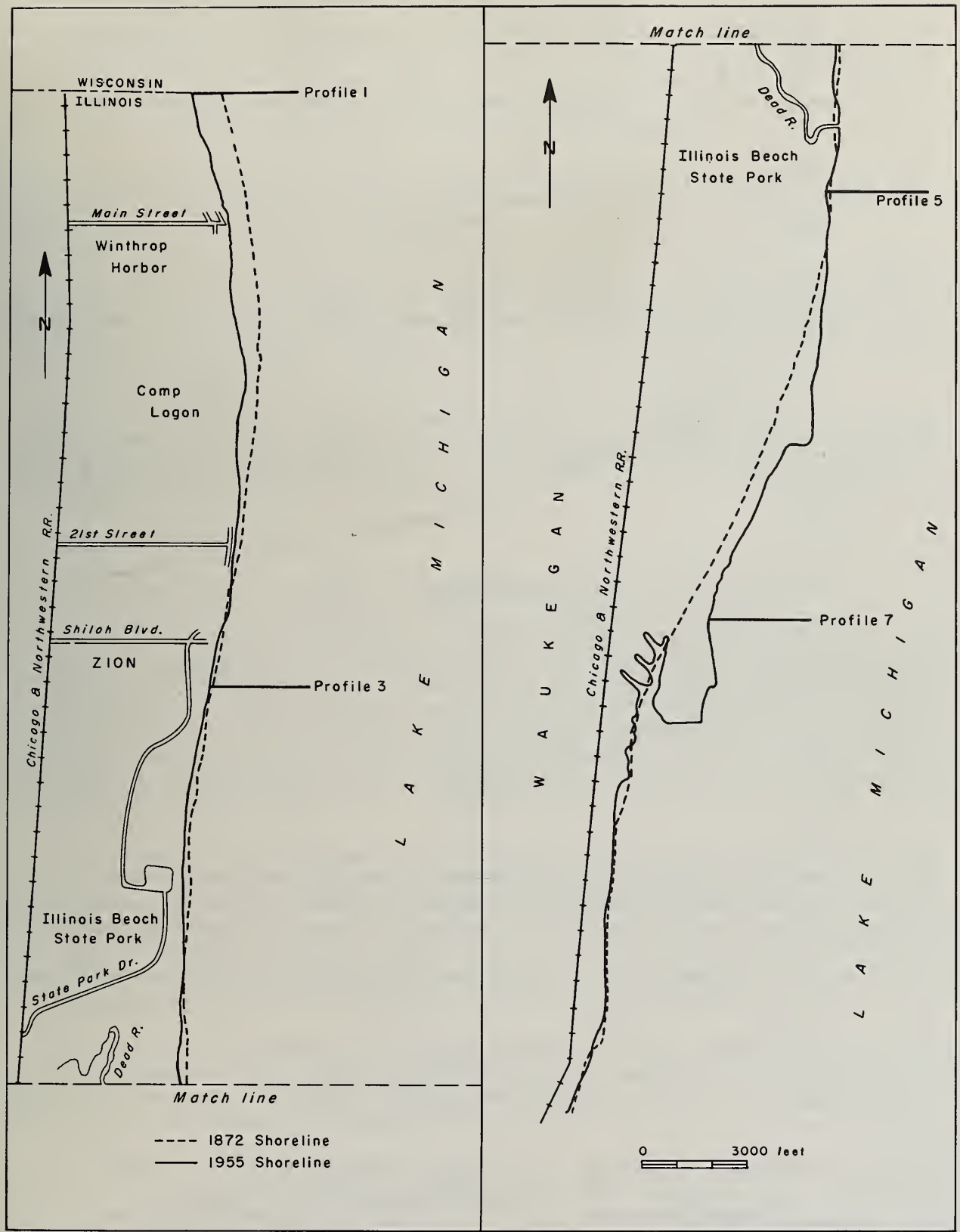


Fig. 19 - Changes in position of shoreline from 1872 to 1955. Taken from map by Illinois Division of Waterways, 1958.

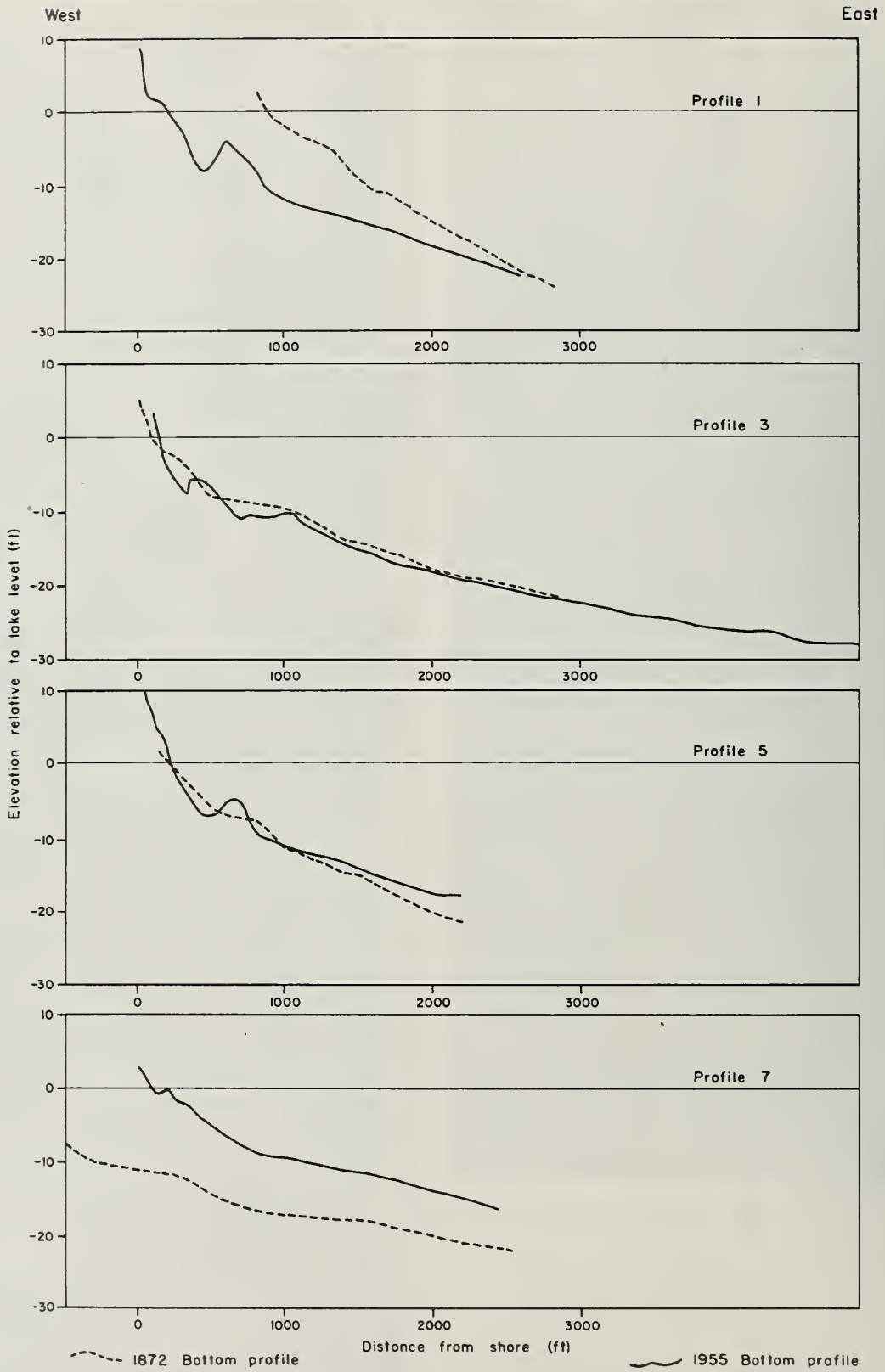


Fig. 20 - Bottom profiles along the shore of the beach ridge complex show changes between 1872 and 1955. For locations see figure 19. Taken from map by Illinois Division of Waterways, 1958.

Figure 20 also demonstrates this general trend of erosion to the north and deposition to the south. The diagram shows the changes of the lake-bottom profiles in three areas along the coast. Profile 1, located just south of the Wisconsin-Illinois state line, shows that the lake bottom has decreased in elevation out to a distance of 2500 feet from shore as material has been removed. In addition it shows the shoreline has moved west.

Profiles 3 and 5, located near Illinois Beach State Park lodge and just south of Dead River, respectively, show a shoreline and bottom profile that are essentially stable, with only minor fluctuations in position.

Profile 7, located at the southern margin of the sand body, however, shows a shift of the shoreline eastward and a build-up of the bottom profile. The change indicates that during the 80-year period material has moved into the area and has been deposited along the coast; it also has built up the subaqueous portion of the beach ridge complex.

Taken together, these diagrams emphasize the migration of the whole sediment body southward. They also demonstrate that a broad apron of sand is first formed under water, and it is on this apron that the subaerial portion of the beach ridge complex builds up.

CONCLUSIONS

The beach ridge complex, of which Illinois Beach State Park is a part, consists of a large body of sediment that has undergone considerable change during historic times as a result of forces generated by the Lake Michigan system. During storms the lake system can be very destructive, particularly at times of high-lake levels. Because a beach ridge complex is a migrating sediment body constructed and kept in motion by high-energy processes, it is important to realize that the same processes that construct certain areas will, in time, partially or completely destroy them.

The total displacement of the beach ridge complex southward is a result of erosion at the north, transportation of the displaced sediment by the lake forces, and deposition of the sediment at the southern end of the complex. This normal process has caused truncation of the beach ridges (loss of land) with associated Lake Michigan transgression in the northern portion of the study area and eastward and southeastward accretion of beach ridges (addition of land) accompanied by regression of the lake in the southern portion.

Erosion has been an important natural geologic process in the development of the beach ridge complex. This process has only become a problem since man has occupied the nearshore areas, and it will continue to be a problem in the future, particularly at times of high-lake level.

Man's attempts to protect these areas by trying to alter the natural processes frequently upset the delicate balance that nature creates, and they unintentionally accelerate destruction in other areas. An understanding of the sedimentological processes of this beach ridge complex is needed before effective plans for long-term use of this area can be made.

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